

## **Earth System Science Pathfinder-3 (ESSP-3) Announcement of Opportunity**

### **INTRODUCTION**

The National Aeronautics and Space Administration (NASA) announces the opportunity to conduct space missions and acquire the data to understand high priority but least understood Earth System processes, or where we have very limited understanding of the controlling forces on the Earth System and the Earth's response to such forcings.

Additional information on NASA's Earth Science and Applications priorities for this announcement is provided in Section 2, Appendix A of the Announcement of Opportunity (AO) and through appropriate links found on the Office of Earth Science homepage at Internet address <http://www.earth.nasa.gov>.

### **ANNOUNCEMENT OBJECTIVES**

This AO invites proposals for the next set of ESSP missions. Proposals are invited for complete investigations of significant Earth System Science questions that meet the objectives of the NASA Earth Science program defined above.

Only proposals to execute complete flight missions through archival and dissemination of data to the scientific community will be accepted. Proposals describing only portions of a mission or that do not address all phases from definition through operations and delivery of data will be deemed not responsive to the AO and will be returned to proposers prior to evaluation. Even if elements of the proposed mission are contributed or commercially provided, as in a data buy arrangement, these elements must be described in your proposal in order to allow NASA to assess the risk of successful implementation and delivery of the data. NASA will evaluate all aspects and elements of the mission against the criteria in this announcement.

The objective of this announcement is to select and fund through launch and science data archival and dissemination, nominally two or three new ESSP missions. Nominally, three or four proposals will be selected and funded for mission formulation, i.e., mission definition, preliminary design, and risk reduction activities. At the end of formulation, NASA will conduct a Mission Design Review (MDR) for each mission. Upon completion of the MDR, NASA will select nominally two or three missions to proceed with a Mission Confirmation Review (MCR) and possible implementation leading to eventual flight.

### **RESEARCH OBJECTIVES**

#### **Programmatic Context:**

The mission of NASA's Earth Science Enterprise (ESE) is to develop a scientific understanding of the Earth system and its response to natural or human-induced changes,

thereby improving the predictive capabilities for climate, stratospheric ozone, weather, and natural hazards. Through its science research programs, the ESE aims to acquire a deeper understanding of the components of the Earth system and their interactions. These interactions occur on a continuum of spatial and temporal scales ranging from local and regional to global scales and from short-term weather to long-term climate scales. The Enterprise also seeks to provide accurate assessments of changes in the chemical composition and physical state of the atmosphere; in the extent and health of the world's forest, grassland, and agricultural resources; and in geologic phenomena that lead to natural hazards.

NASA shares with other US Global Change Research Program (USGCRP) partners an interest in fundamental studies of the basic processes that govern the Earth system, diagnostic studies of recent and past satellite data records, and model simulations/predictions of global changes. At the same time, effective use of resources requires that the ESE's science strategy be focused on research projects that allow optimal use of NASA's unique capabilities. Compared to the range of investigations embraced by the entire USGCRP, NASA's Earth science program emphasizes measuring changes in forcing parameters, and documenting the natural variability of the Earth system and responses to forcings, especially through space-based measurements. Space-based measurements can provide global coverage, high spatial resolution, and/or temporal resolution, in combinations that cannot be achieved by conventional observational networks.

The *Research Pathways* report (NRC, 1999a) formulated a wide range of research imperatives and scientific questions that require investigation across the field of Earth system science. Choosing among all potentially important research questions is a judgment of scientific value. In the context of NASA's Earth science research program, the principal scientific priority criteria are the spatial scale, temporal duration, and the nature and magnitude of the phenomena being investigated, as well as anticipated return in terms of reducing the uncertainty in understanding and documenting potential changes in the Earth system.

Research questions that address Earth system dynamics at ***large regional to global scales*** are those of greatest interest for the ESE. This is particularly true for regions where only limited conventional (non-space) observations are available (e.g., the atmosphere over the open ocean and polar regions, continental ice sheets, etc.). For example, ESE's atmospheric chemistry research has been focused on global scale chemical processes rather than local air quality, which is typically the responsibility of regulatory environmental agencies.

Likewise preference is given to the study of phenomena and processes that may induce lasting changes in the Earth system, typically ***seasonal and longer period responses***, as well as changes that are irreversible in the foreseeable future. Understanding and predicting fast processes (e.g., the development of weather systems, trace gas emissions) may be essential in order to quantify longer-term average impacts. While forecasting individual environmental phenomena is not a primary ESE objective, further developing

experimental prediction of specific events (e.g., weather disturbances) that can be verified by observation is a fundamental research tool for understanding changes in climate and the global environment (e.g., mean displacement in storm tracks). At the process level, priority is given to those processes that have the potential to induce *large impacts* and/or are the root of large uncertainty in the overall response of the Earth system.

NASA is a research and development agency, dedicated to maintaining leadership in space research, technology, and missions. Common to all NASA Enterprises is the objective of introducing technical innovations in sensor and platform design, and integrating these new capabilities in flight mission programs. Although not the place to develop new technology, NASA's research and development mission guarantees a strong commitment to expanding knowledge of the Earth through new types of global environmental observations. Investigators seeking to develop new technologies or whose mission concepts do not meet the mission readiness constraint described in section 3.1.2 of the AO are encouraged to consider proposing to NASA technology development competitions, such as those for the New Millennium Program (NMP) or the Instrument Incubator Program (IIP).

NASA initiated the Earth System Science Pathfinder (ESSP) project to provide a flexible opportunity to stimulate new scientific understanding of the global Earth system by encouraging innovation in instrumentation and strategies for acquiring and distributing new datasets. The program seeks to reward creativity in all aspects of mission development and to encourage increased participation and innovative ideas in studies of interactions of components of the Earth system and in measurements of key variables from space. The philosophy behind ESSP embraces small satellite missions addressing high priority Earth System Science objectives where the scientific focus of the program will naturally evolve with our enhanced understanding. Thus, the strategy for this ESSP AO is to solicit unique Earth Science missions that address one or more of the unanswered science questions in the NASA Earth Science Research Strategy for 2000-2010.

ESSP is a science-driven project intended to identify and develop low-cost, quick turnaround spaceborne missions. The National Academy of Sciences (NAS) recommended that ESSP pursue scientific objectives that are not being directly addressed by current or approved programs (NAS/NRC document FO-2080, 1995). As such the ESSP Project is intended to address exploratory measurements which can yield new scientific breakthroughs and can deliver conclusive scientific results addressing a focused set of scientific questions. In some cases, this may involve measuring several related parameters to allow closure tests to be carried out. In other cases, an exploratory mission may focus on a single pioneering measurement that opens a new window on the behavior of the Earth system.

It is the goal of the ESSP Project to sustain a launch rate of at least one mission per year. As such, ESSP will provide periodic windows of opportunity to accommodate new scientific priorities by conducting a series of focused missions to answer critical Earth System Science questions not currently addressed NASA's Earth Science Enterprise. By conducting ESSP missions on a regular basis, NASA provides a mechanism to

continuously enhance Earth Science and Applications Programs that are evolving based on new knowledge and changing national priorities.

### **Scientific Questions:**

Establishing research priorities becomes a major challenge when priorities cross a number of different disciplines, each embracing a large set of scientific questions. The challenge facing the ESE is to balance competing demands in the face of limited resources and chart a program that addresses the most important and tractable scientific questions and allows optimal use of NASA's unique capabilities for global observation, data acquisition and analysis, and basic research. To this end, choices need to be made between many projects, all of which are important, timely, and ready to succeed. Most significant from a strategic perspective are the choices between different but equally promising candidate space flight missions or measurement systems.

Thus, NASA's selection of priorities involves both scientific needs and implementation realities. Scientific considerations are paramount and start the prioritization process. These considerations determine what science questions, and ultimately which missions and research projects shall be pursued. Purely scientific considerations are followed by considerations of science-related context (e.g., benefit to society, mandated programs), followed in turn by implementation considerations. The latter, such as technology readiness, tend to influence the order in which science projects are pursued and the final shape they may take. These practical considerations often result in some feedback and iteration of project selection.

The key research topics studied by NASA's Earth Science Enterprise fall largely into three categories: forcings, responses, and the processes that link the two and provide feedback mechanisms. This conceptual approach applies to all research areas of NASA's Earth Science program. The scientific strategy to address this complex problem can be laid out in five fundamental questions, each raising a wide range of cross-disciplinary science problems.

- *How is the global Earth system changing?*
- *What are the primary forcings of the Earth system?*
- *How does the Earth system respond to natural and human-induced changes?*
- *What are the consequences of change in the Earth system for human civilization?*
- *How well can we predict the changes to the Earth system that will take place in the future?*

While these five questions define a logical progression in the study of global change, each one covers a range of topics too broad to serve as a simple guide for program implementation. For this purpose, more specific research questions need to be formulated and prioritized. The ESSP Project is designed to both complement and extend the existing ESE flight program strategy. This third ESSP AO seeks to address the following Earth science research priorities and associated questions based on a logical progression of our current understanding.

## **Earth System Variability and Trends**

- How are global precipitation, evaporation, and the cycling of water changing?

## **Primary Forcings of the Earth System**

- What trends in atmospheric constituents and solar radiation are driving global climate?
- How is the Earth surface being transformed, and how can this information be used to predict future changes?

## **Earth System Responses and Feedback Processes**

- What are the effects of clouds and surface hydrologic processes on climate change?
- How do ecosystems respond to and affect global environmental change and the carbon cycle?
- How can climate variations induce changes in the global ocean circulation?
- How do stratospheric trace constituents respond to change in climate and chemical composition?
- How is global sea level affected by climate change?
- What are the effects of regional pollution on the global atmosphere, and the effects of global chemical and climate changes on regional air quality?

NASA will consider scientifically compelling proposals based on other scientific questions, but proposers shall provide a clear and concise justification in the Step 1 proposal.

These research priorities encompass the traditional disciplines of atmospheric chemistry and physics, solid Earth, oceans and ice, ecosystems, natural hazards, and applications, and are intended to impart a problem focus on the satellite observational activities conducted under the aegis of NASA's Earth Science Enterprise.

The initial ESSP Announcement of Opportunity emphasized scientific investigations within all areas of Earth System Science. However, the offerors had to demonstrate that the proposed investigations complemented NASA's existing and/or approved flight program, which was largely embodied by the Earth Observing System (EOS). Further, it was intended to encourage missions which could serve as either gap-fillers or which could provide new types of global "foundation" datasets. The second ESSP Announcement of Opportunity reflected the approaching launch of the initial EOS missions and the continuing development of the missions selected in the first ESSP AO. While not precluding innovative proposals for missions that address critical issues in areas for which there are approved flight programs, the second AO sought unique missions that demonstrate a scientific focus clearly beyond the scope of existing programs.

This ESSP Announcement of Opportunity seeks unique missions that demonstrate a scientific focus on priority areas identified above and are clearly beyond the scope of existing and/or approved missions. NASA will consider proposals based on other compelling scientific questions/priorities, however it remains up to the proposers to articulate the overall scientific benefit of any missions that seek to improve upon planned measurement sets.

ESSP missions are intended to be science-driven. Proposers are required to quantify how the new observations will contribute to the state of knowledge toward one or more chosen science questions by means of a sensitivity analysis and science traceability matrix that illustrate the anticipated improvements in the state of knowledge/understanding as a result of reductions in uncertainty.

The NASA Earth Science Enterprise integrates a broad suite of observational and monitoring objectives in the context of the USGCRP. Specific program elements are summarized in several key science documents (see AO Appendix B: “Contents of the ESSP AO-3 Library”).

The following Internet World-Wide-Web Homepages (URL addresses) may provide additional information of interest:

NASA Earth Science Enterprise Homepage: <http://www.earth.nasa.gov/>  
NASA ESE Missions: <http://www.earth.nasa.gov/missions/index.html>  
ESSP Project Homepage: <http://essp.gsfc.nasa.gov>  
ESSP-3 Announcement of Opportunity Homepage <http://essp.larc.nasa.gov/essp>  
EOS Project Office Homepage: <http://eospsso.gsfc.nasa.gov/>  
NASA’s New Millennium Program: [http://nmp.jpl.nasa.gov/index\\_flash.html](http://nmp.jpl.nasa.gov/index_flash.html)

In summary, the ESSP Project is designed to augment the global measurement objectives of the USGCRP as well as other strategic Earth Science objectives outlined by the National Academy of Sciences. As such, the ESSP Project seeks to:

- Provide new observations that will contribute to the state of knowledge toward one or more chosen science questions
- Provide space based measurements complementary to those directly supported by the NASA Earth Science baseline missions (i.e., EOS and Earth Probes observational data sets)
- Avoid duplicating observational objectives currently supported by means of existing NASA Earth Science Missions (e.g., GRACE, CloudSat, PICASSO-CENA, etc.)
- Avoid duplicating observational objectives supported by existing or approved commercial, national, or international global Earth Science Missions (e.g., Ikonos, POES, GOES, ADEOS II, ALOS, ENVISAT, METOP, etc.)